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E-Health Interventions for Depression, Anxiety Disorder, Dementia, and Other Disorders in Old Age: A Review

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Abstract

E-health interventions targeting older adults seem to be a promising approach in domains including depression, anxiety disorder, and dementia – three of the most prevalent mental disorders in old age. Further, these technical innovations (e.g., ambient assisted living and smart homes, game-based applications and training programs) may have the potential to compensate for or prevent health-related changes or to foster active aging. As highlighted by this literature review, however, research in this area is still at an early stage. The methodological quality of the studies and projects differs, and there is a lack of randomized controlled trials and robust research designs (much research to date has been limited to pilot and short-term studies). Advantages and challenges of using information and communication technology applications in the above-mentioned domains are discussed, as are user characteristics.

Keywords: e-health, older adults, depression, anxiety disorder, dementia

Introduction

E-health research focusing on the second half of the lifespan is still scarce. However, there is growing interest in the field and initial results are promising. A particular point of interest is whether older adults are familiar with information and communication technology (ICT) facilities such as computers and the Internet, and are thus able to benefit from health services provided through these media. A further question is whether these new media meet the needs of elderly people and have the potential to foster active and healthy aging. Kryspin-Exner and colleagues (Kryspin-Exner, Oppenauer, Preschl, & Maercker, 2009) have discussed e-health applications targeting older users and their caregivers, including assistive technology, tele-medicine, tele-monitoring, psycho-education, and support via the Internet. Further, older people are sometimes included in the adult samples of studies evaluating Internet-based therapeutic interventions, and increasing numbers of projects in this domain focus specifically on older adults. Against this background, this paper reviews research on e-health interventions involving older adults and their caregivers. We identified relevant articles, abstracts, and conference proceedings published in German or English by searching the appropriate databases (MEDLINE, Premedline, PsycCritiques, PsycINFO, PSYNDEXplus, PubMed/Medline, Web of Science) and the Internet (using google and google scholar) and by screening reference lists and the archives of the journal *Gerontechnology*. We searched for terms such as e-health, e-mental health, Internet, online, technology, intervention, therapy, old age, older people, caregivers, significant others, family members, gerontechnology, depression, anxiety, dementia, mobility, ambient assisted living, monitoring, and healthy ageing (in various combinations). Because the number of completed high-

quality studies in the field is limited, we also included reports on ongoing projects. Information on all of the articles included in the review is provided in Table 1.

A necessary condition for any technical device being used in old age is that the technology meets the needs of older adults and is accepted by this target group. Charness and Boot (2009) discussed research on attitudes toward technology in old age, as well as age-related changes in the perceptual, cognitive, and motor abilities that influence successful technology use. The authors concluded that age-related differences in technology use may decline over time, but will not disappear in future generations for two reasons. First, older people will continue to experience changes in their perceptual, cognitive, and motor abilities; second, technological development will continue to advance rapidly. It may be possible to decrease age-related differences further if product designers consider psychological guidelines (see Oppenauer, Preschl, Kalteis, & Kryspin-Exner, 2007, for a review of technology use in old age from a psychological perspective). Technology that considers and meets the needs of individuals across the lifespan is labeled gerontechnology: “[…] It helps support ‘successful aging’ […]. It focuses on the total human life-span […] and the encompassing of all domains of human activity. An enhanced quality of life in older adults is the ultimate goal of gerontechnology.” (Bronswijk et al., 2009, p. 3).

Areas of E-Health Applications in Old Age

The Berlin Aging Study (BASE; Wernicke, Linden, Gilberg, & Helmchen, 2000) found *depression, anxiety disorder,* and *dementia* to be some of the most frequent mental disorders in old age. Many older people suffer from mild or subsyndromal depression and show symptoms that do not reach the threshold criteria for Major Depressive Disorder (Forstmeier & Maercker, 2008; Maercker et al., 2008).

Frequency of subsyndromal depression is related to age, polypathia, functional limitation, and need for help. In the following, we discuss the available research on e-health interventions for (1) depression, anxiety, and posttraumatic stress disorder (PTSD), and (2) dementia. As mentioned above, details of all studies described are presented in Table 1.

E-Health Applications for Depression, Anxiety, and PTSD

Samples in randomized controlled trial (RCT) studies of Internet-based therapeutic interventions for depression, anxiety, and PTSD often include older adults. Although these studies do not focus specifically on the second half of the lifespan or on age differences, their findings indicate that both older and younger individuals benefit from these interventions.

To our knowledge, findings from only one completed RCT study on e-health and depression in old age have been published to date. Focusing on older adults (aged 50–75 years, *N* = 301), Spek and colleagues (Spek, Cuijpers, et al., 2007) demonstrated that an Internet-based cognitive behavioral self-help intervention was effective in older people with subthreshold depression (BDI-II score below 20; Beck, Steer, & Brown, 2006). Relative to a waiting list control condition, the authors found a moderate effect size (0.55) for the Internet-based intervention – similar to the effects reported for an offline group cognitive behavior therapy intervention. Results from a one-year follow-up showed that these effects persisted over time (Spek et al., 2008).

An example of research on PTSD (secondary outcomes: depression, anxiety, etc.) in old age is a study currently being conducted by Knaevelsrud, Böttche, and Kuwert (2009, 2010) with adults aged 65 years and above (see www.lebenstagebuch.de). The sample currently comprises 74 patients who

experienced traumatic situations as children, during or shortly after the end of World War II. These patients participated in a standardized, Internet-based cognitive behavioral writing therapy (Integrative Testimonial Therapy). Over six weeks, the patients wrote eleven texts and received feedback from a therapist. Results from 74 participants showed (among others) a decrease in PTSD symptoms (PDS, Foa, Cashman, Jaycox, & Perry, 1997) and depression (BSI, Derogatis, 1992).

Recently, Gamito and colleagues (2010) presented results from a pilot study (*N* = 10 war veterans, mean age: 63 years) on virtual reality exposure therapy (VRET). Participants were assigned to the VRET group (exposure to a virtual war scenario in 12 sessions), to control group (exposure in imagination), or to a waiting list. First results from this study showed a reduction in PTSD (CAPS, Blake, Weathers, Nagy et al., 1992) and psychopathological symptoms (SCL-90-R, Derogatis, 1994) in the VRET group.

The Butler system provides several *depression and anxiety* modules for older users (Botella et al., 2009). The system contains two therapeutic modules based on life review and autobiographical memory: the *therapeutic book of life* and positive mood induction modules for depression and anxiety. The latter are *Virtual Environments (VE)* in which the user learns techniques to reduce negative mood and to recall positive autobiographical memories. The *book of life* is a 3D adaptation of a book containing several chapters that can be customized by users (to include text, pictures, and Mp3 music files). Besides therapeutic modules, the Butler system offers diagnostic (depression and anxiety) and “playful”/social interaction modules. All applications are guided by a personalized icon, the so-called “butler.” Results from a pilot study (*N* = 4, pre-post comparison) showed an increase in positive emotions and a decrease in negative emotions in older users (visual analogue scales; Botella et al.,

2009). In addition, the participants reported high levels of satisfaction and experienced little difficulty in using the system.

We are currently using the depression modules of the German version of the Butler system as supplements to a face-to-face setting in an intervention study with older adults aged 65 to 75 years who show mild to moderate depression (Preschl, Wagner, Forstmeier, & Maercker, 2010). The treatment is based on recent advances in the context of life review interventions (Bohlmeijer, Smit, & Cuijpers, 2003; Haight & Haight, 2007; Maercker, 2002; Maercker & Zöllner, 2002; Serrano, Latorre, Gratz, & Montanes, 2004) and computerized mood induction (Banos et al., 2004; Banos et al., 2005; Riva et al., 2007) in old age. Both parts of the intervention focus on inducing positive memories and positive mood. Results from a pilot study (N = 3) show a decline in depressive symptoms (BDI-II, Beck, Steer, & Brown, 2006), an increase in quality of life (WHO-5, WHO 1998), as well as good participant acceptance of the computer modules (exploratory data). Further, the participants reported improvements in meaning of life (LAP-R, Mehnert, Müller, & Koch, 2007) and reminiscence strategies (RQ, Mayer, Filipp, & Ferring, 1996). We are currently conducting an RCT study (waiting list control condition) focusing on these outcome variables.

Rosenberg and colleagues (2010) recently presented results from a pilot study of a game-based intervention for older adults with subsyndromal depression. Nineteen older adults aged 63–94 years participated in a 12-week physical activity program based on Nintendo's Wii sports (five games: tennis, bowling, baseball, golf, and boxing). Results showed improvements in depression (QUIDS, Rush, et al., 2003), mental health-related quality of life (SF-36, Ware & Sherbourne, 1992), and cognitive performance (RBANS, Randolph, Tierney, Mohr, & Chase, 1998).

E-Health Applications for Dementia Patients and Their Caregivers or Significant Others

We identified three RCT studies and several ongoing projects, as well as work to develop and evaluate various prototypes. The REACH project (Resources for Enhancing Alzheimer's Caregiver Help) is an initiative for caregivers of people with (mild to moderate) Alzheimer's disease (Schulz et al., 2003). This six-site project in the USA investigated a variety of interventions (e.g., monitoring of caregiver stress, computerized telephone support). Between 100 and 257 caregivers (mean age: 61.1–68.5 years) participated in RCT intervention studies at each site. Caregivers showed reduced stress and higher skill acquisition after the intervention (main outcome measure: CES-D, Radloff, 1977).

Results from an RCT study (N = 66) of an Internet video-conferencing group intervention program for family caregivers of older adults with Alzheimer's disease, stroke-related dementia, or Parkinson's disease showed a decline in stress (3-point scale measuring severity of experienced stress and RMBPC, Teri, et al., 1992) among the participants after 10 weeks (Marziali & Donahue, 2006). Note that the caregivers were older adults themselves, with an average age of 67.8 years.

Mahoney, Tarlow, and Jones (2002) evaluated a preventive multimedia program (CD-ROM) providing psycho-education about symptoms of Alzheimer's disease and "normal" memory loss. Their RCT study involved 113 older adults (mean age: 72 years). Beside promising results on the usability of the program, the authors reported highly significant differences between the intervention and the control (no program) groups, with individuals in the intervention group showing significantly more knowledge about memory loss (KMLT, Mahoney, Tarlow, & Jones, 2002).

Pot and Blom (2009) are currently conducting a web-based intervention program (online counseling) for family caregivers of people with dementia. To date, 60 individuals have started the intervention program, which involves eight sessions plus a booster session one month later. The aim of the intervention, called *mastery over dementia*, is to reduce depressive symptoms and caregiver burden and to improve coping strategies.

Riikonen, Mäkelä, and Perälä (2010) have evaluated 29 technologies for dementia patients (age range: 54 to 90 years), including risk-prevention technology (e.g., cooker/door alarm, monitoring system), assistive technology (e.g., electronic medication dispenser), and emergency technology (e.g., safety alarm telephone, monitoring system). Results obtained from 25 individuals with dementia and their family caregivers show that these devices have the potential to prolong independent living and to reduce caregivers' stress (NPI, Cummings et al., 1994).

Recently, Alm and colleagues (2009) presented positive (essentially qualitative) results for three technological approaches focusing on the provision of enjoyable activities for people with dementia (N = 5–40 depending on the prototype). An interactive system provides entertainment, facilitates communication, and fosters creativity in this target group. In a 3D environment, users have various options to explore and enjoy virtual surroundings (a hothouse in a botanic garden, a museum, and an old-fashioned pub), play games, be creative (e.g., paint a virtual pot or compose a piece of music), or enter into conversation via a system called CIRCA. The idea of CIRCA is to facilitate communication between people with dementia and their carers using individual reminiscence (video, music, and photographs) and to overcome the barriers of short-term memory loss that often obstruct communication.

Libin and Cohen-Mansfield (2004) have investigated the use of therapeutic robotic pets (two cats) for patients with dementia in a setting similar to traditional pet

therapy. As dementia patients may no longer be able to care for a real pet, a robotic pet could function as an alternative. Results of a pilot study showed decreased agitation and increased pleasure and interest after engaging with the robotic pets. Another robotic pet for dementia patients is AIBO (Yonemitsu, Higashi, Fujimoto, & Tamura, 2002). In a case study (*N* = 4), AIBO was found to enhance communication with the robotic pet as well as among patients. Further, Odetti and colleagues (2007) have presented positive results on acceptance of the system (*N* = 23, mean age of participants: 76.6 years).

An example of ongoing research in the field of dementia is the COGKNOW project. Dröes and colleagues (2009) have recently developed a prototype electronic assistant providing older people with mild dementia with support in the domains of memory, social contact, daily activities, and psychological distress (*N* = 90 older adults and caregivers were involved in the design process). Another ongoing project is the development of the ALADDIN platform aiming to support patients and their caregivers in terms of disease self-management (Haritou, 2009). The system will monitor patients' health parameters and assess cognitive and behavioral functions as well as activities of daily living. Further, ALADDIN will provide risk assessment, security features, and social network utilities. Another system that may be more relevant at an advanced stage of dementia, when patients at increasing risk of getting lost, is the Global Positioning System (GPS) currently being developed by Willemse, Horjus, and Pot (2009). It has been suggested that this system will help people with dementia to live independently in familiar surroundings for as long as possible.

The ENABLE project (http://www.enableproject.org/index.html) also merits consideration. The general aim of this project was to develop and evaluate technical devices for people with dementia: devices to support memory (e.g., medication

reminder), to provide pleasure and comfort (e.g., a picture gramophone), and to facilitate communication (e.g., a pre-programmable telephone). Results showed that the products tested could help people with dementia, but the successful use of a device was related to its operational reliability. Technology for this target group needs to be comfortable, secure, and safe.

More Complex Age-Appropriate Approaches

Individuals in the second half of the lifespan face challenges in a variety of domains: decline in sensory, motor, and cognitive abilities; multi-morbidity and chronic disease; difficulty performing Activities of Daily Living (ADL) and instrumental Activities of Daily Living (IADL) (bathing, dressing, preparing meals, shopping, leisure activities, etc.); and changes in social relationships (Forstmeier & Maercker, 2008). Interventions are thus needed to facilitate active participation in social life as well as physical and mental wellbeing across the lifespan – that is, to foster *active aging*: "Active Ageing is the process of optimizing opportunities for health, participation and security in order to enhance quality of life as people age" (WHO, 2002, p. 12). Key components of this concept are autonomy, independence, quality of life, and a healthy life expectancy. In the following, we present findings from studies of ICT interventions designed to foster active aging and to compensate for or prevent common health-related changes in old age.

Ambient Assisted Living (AAL) and Smart Homes

Ambient assisted living (AAL) and smart homes are technologies designed to enhance older people's quality of life and to help them remain independent (i.e., in their own homes) for as long as possible (Chan, Campo, Esteve, & Fourniols, 2009; Demiris, 2008; Huch, 2009). These devices are developed to compensate for age-related changes in domains such as mobility/safety and sensory, memory, or social skills, and to provide help with ADLs or to monitor health parameters in case of chronic disease. The common ground of these initiatives is that they foster in-home

self-care, as opposed to hospital/institutional care (Chan et al., 2009; Huch, 2009), thus prolonging independent living and helping to combat the increasing costs of health care systems in aging societies. Chan and colleagues (2009) have identified ethical and legal issues and individual needs that have to be considered in this context, especially with regard to monitoring devices. For example, it is significant whether or not users are able to make an informed choice and give informed consent. Further, the privacy concerns of monitored users have to be considered (Chan et al., 2009; Charness & Boot, 2009). Privacy can be increased by using less invasive technology, such as monitoring systems that do not allow the user's face to be clearly identified (Caine, Fisk, & Rogers, 2006). In the following, we provide some examples of smart home and AAL solutions in the above-mentioned domains. To our knowledge, no RCT studies have yet been conducted in this field; research in this area is still at a very early stage.

The COGKNOW project (Dröes et al., 2009) is an example of a smart technology solution providing memory and social support. For example, the system can remind the user to telephone a significant other or to close the front door. If the user wants to phone a family member or friend, the system automatically connects to that person. Assistive social robots are another kind of smart solution facilitating social contact. In their review of research in this area, Broekens, Heerink, and Rosendal (2009) drew attention to the lack of RCTs and robust research designs (much of the research to date has been limited to pilot and short-term studies). The reason for these deficits may be that research in this domain – as in other e-health domains in old age (Chan et al., 2009) – is in its early stages (no studies about assistive social robots were published before 2000). Beyond these concerns, the existing research on assistive social robots has provided limited qualitative and

quantitative evidence for positive effects of these technological solutions on health and psychological well-being in old age.

GEROHOME is an example of an automatic monitoring system of ADLs such as preparing a meal (Anfosso & Bourdeau, 2009). Preliminary results from two case studies (with participants aged 64 and 85 years) indicate that the system is able to detect different ADL levels. Franco and colleagues (Franco, Gallay, Berenguer, Mourrain, & Couturier, 2008) presented similar results, showing that another monitoring system (*N* = 13, mean age: 83) was able to differentiate daily and nocturnal ADL levels. The idea behind automatic monitoring of ADLs is to gain further insights into physical and mental health conditions and to identify problems, thus informing the development and targeted implementation of preventive and support measures. There are two main monitoring approaches (Anfosso & Bourdeau, 2009). One is to measure bio-signals such as blood pressure or body temperature in people with chronic disease by means of wearable devices (Bestente et al., 2008; Lee et al., 2008). These data are sent to and recorded at a local base station and provide caregivers with information about the health status of the older person, allowing them to initiate (emergency) assistance where necessary. The other main monitoring approach is to use sensors embedded in the house (e.g., to warn the resident that the oven is on). Recently, Reder, Ambler, Philipose, and Hedrick (2010) conducted a pilot study (*N* = 12, age 55+ years) involving remote monitoring of four domains (meal preparation, physical activity, vitamin use, and personal care) with older adults and their caregivers over a 3-month period. Results from qualitative interviews indicated satisfaction with the system and positive outcomes on various psychological variables (perceived safety, well-being, peace of mind, independence). However, the subjects identified privacy concerns and technical problems as barriers.

In a short overview, Huch (2009) introduced the Ambient Assisted Living for Europe initiative, including a variety of ongoing international projects (listed in Huch, 2009, p. 114). The VITALIshoe project (Hlauschek, 2009) is an example of a technological device designed to promote mobility/safety. This instrumented shoe was developed to prevent falls by monitoring motion patterns and training balance, thus enhancing the activity levels of older adults on the long term. In the sensory domain, the Hear Me Feel Me project (http://www.hearmefeelme.org) uses mobile phone technology to compensate for visual impairment. In this approach, a mobile phone provides speech synthesis and audio input and output as well as the possibility to connect to the Internet. The user can thus access several services: medication and medicine-related information and services, health monitoring, and diet information.

Game-Based Applications and Training Programs to Foster Active Aging

Fozard, Bouma, Franco, and Bronswijk (2009) have discussed the use of technology to address the needs of this target group beyond health-related challenges – specifically, the use of leisure technology to help older adults have fun and to enjoy life. Although the authors concluded that little is known about the application of these technologies in this context, some research in this field is available. Gamberini and colleagues (Gamberini et al., 2008) reviewed game-based applications for older people, finding them to have positive affects on cognitive abilities as well as on social and emotional variables. The ElderGames project is an example of a game-based technology that allows older users to play and interact together while implicitly their training problem-solving strategies, psychomotor

abilities, etc. (Gamberini et al., 2006; Gamberini et al., 2008). The authors report good results in terms of usability (*N* = 4, mean age: 68 years), acceptance (*N* = 107) and monitoring of cognitive abilities (*N* = 59) (Gamberini et al., 2009). Further, Basak, Boot, Voss, and Kramer (2008) showed that playing a strategy video game enhanced cognitive functioning in older adults. After participating in a game tutorial, the participants (20 in a training group, 20 in a control group) spent a total of 23.5 hours over 4 to 5 weeks playing the game. Another program focusing on physical and social interaction is Age Invaders (Khoo, Merritt, & Cheok, 2009). In this game, various family members (children, parents, and grandparents) play together via the Internet (e.g., avoiding laser beams). The system was tested with 7 older players aged 64–78 years; findings on its usability were encouraging. Finally, Charness and Boot (2009) discussed the effects of games on cognitive and perceptual abilities and well-being. The authors found positive results in this field to be limited (e.g., self-reported functioning). Further research should focus on more objective outcome measures and on the transfer of the trained functions to real life.

Further, there is some literature on game-based and rehabilitation programs for motor and other abilities. Erren-Wolters and colleagues (Erren-Wolters, van Dijk, de Kort, Ijzerman, & Jannink, 2007) reviewed the literature on virtual reality applications designed to train the mobility of younger and older people. The authors found the methodological quality of the studies to range from poor to fair. Again, these findings testify to the novelty of the field, with research still being in its early stages. Nevertheless, first results seam to indicate the potential of virtual reality applications to train mobility and thus foster the real-life use of mobility devices. For example, Giotakis, Tsirgogianni, and Tarnanas (2007) presented findings from a rehabilitation training program based on virtual reality exposure therapy (VRET). During the intervention, 68 older adults (mean age: 76.8) completed several tasks

(e.g., walking on virtual slippery streets). Results show reduced fear of falling (FES-I, Yardley et al., 2005) and increased balance confidence (ABC, Powell, & Myers, 1995). TheraGame is another example of a virtual reality training program in which the user learns to navigate virtual objects (Kizony, Weiss, Shahar, & Rand, 2006). Results from 12 healthy older adults and 4 patients with neurological deficits aged 65 to 76 showed that enjoyment and usability of the system were high. Likewise, Rand, Kizony, and Weiss (2008) found a virtual reality system (Sony PlayStation II Eyetoy) designed to train patients after stroke to have good usability. Ten healthy older adults and 12 stroke patients aged 50 to 80 participated in the usability studies. Participants trained their motor function in a game-based virtual environment (e.g., playing Kung-Foo).

TABLE 1. Articles Included in the Review

Authors (name of project)	**Area of interest**	**Format**	***N***	**Age of participants (in years)**	**Research design**	**Source**	**Selected findings**
	Depression/anxiety			**60–94**			
Botella et al. (2009) (Butler/Mayordomo)	Depression/anxiety	E-Health platform, prototype	4	66–74	Pre-post comparison (pilot study)	Peer reviewed journal	Increase in positive and decrease in negative emotions (visual analogue scale)
Gamito et al. (2010)	PTSD	Virtual reality (VRET)	10	Mean age: 63	Pilot study, waiting list control group and other treatment	Peer reviewed journal	Reduction of PTSD (CAPS) and psychopathological symptoms (SCL-90-R)
Knaevelsrud et al. (2009; 2010)	PTSD, further depression/anxiety	Internet-based therapeutic intervention	74 (ongoing)	65+	RCT, waiting list control group	Conference proceedings	Improvement in PTSD (PDS) and depression (BSI)

Preschl et al. (2010) (Butler)	Depression	E-health supplement to face-to-face setting	3	65–75	Pre-post comparison (pilot study); authors are currently conducting an RCT study (waiting list)	Conference proceedings	Improvement in depression (BDI-II), quality of life (WHO-5), meaning of life (LAP-R), reminiscence strategies (RQ)
Rosenberg et al. (2010) (Nintendo's Wii sports)	Depression	Game	19	63–94	Pre-post comparison	Peer reviewed journal	Improvement in depression (QUIDS), mental health-related quality of life (SF-36), cognitive performance (RBANS)
Spek et al. (2008); Spek, Nyklicek, et al. (2007) (follow-up)	Depression	Internet-based therapeutic intervention	301	50–75	RCT, waiting list control group	Peer reviewed journal	Improvement in depression (BDI)

	Depression/anxiety			**18–75**			
Cavanagh et al. (2006) (Beating the Blues)	Anxiety/depression	Computerized therapy package	219	19–70	Pre-post and follow-up comparisons	Peer reviewed journal	Improvement in self-reported anxiety and depression (single-item 9-point scale)
Kessler et al. (2009)	Depression	Internet-based therapeutic intervention	297	18–75	RCT, waiting list control group	Peer reviewed journal	Recovery from depression (BDI)
Knaevelsrud & Maercker (2007)	PTSD, further anxiety and depression	Internet-based therapeutic intervention	96	18–68	RCT, waiting list control group	Peer reviewed journal	Improvement in PTSD (IES), anxiety, and depression (SCL-90)
Proudfoot et al. (2004) (Beating the Blues)	Anxiety/depression	Computerized therapy package	274	18–75	RCT, control: treatment as usual	Peer reviewed journal	Improvement in depression (BDI)
Wagner, Knaevelsrud, & Maercker (2006)	Complicated grief, further anxiety and depression	Internet-based therapeutic intervention	55	18–68	RCT, waiting list control group	Peer reviewed journal	Improvement in PTSD (IES), anxiety and

							depression (SCL-90)
Wright et al. (2005)	Depression	Computer-assisted intervention (therapist contact and computer sessions)	45	18–65	RCT, waiting list control and face-to-face intervention group	Peer reviewed journal	Improvement in depression (HAMD and BDI)
	Dementia			**54–90**			
Alm et al. (2009) (CIRCA)	Dementia	Multimedia leisure system (prototypes)	5-40 (depending on prototype and phase of the design process)	Not specified (dementia patients and their carers)	Development and evaluation of prototypes	Peer reviewed journal	Positive experience with the prototypes (essentially qualitative results)
Dröes et al. (2009) (COGKNOW)	Dementia, memory, social support	Electronic assistant	90 (45 dementia patients; 45 carers)	Not specified (dementia patients and their carers)	Development and evaluation of a prototype	Conference proceedings	Development of system providing personalized support
Haritou (2009) (ALADDIN)	Dementia	Platform for assisted living	Not specified	Not specified (dementia patients and their carers)	Development and evaluation of a prototype	Conference proceedings	Not specified (onging)
Libin & Cohen-	Dementia	Robotic pet	9	83–98	Experiment, direct	Peer reviewed	Decreased

Mansfield (2004)					observation	journal	agitation; increased pleasure and interest (main outcome measure: ABMI)
Mahoney et al. (2002)	Dementia, memory loss	Preventive multimedia program (CD-ROM)	113	Mean age: 72	RCT (use vs. non-use of program)	Peer reviewed journal	More knowledge about memory loss in the IG (KMLT)
Marziali & Donahue (2006) (Caring for Others)	Dementia and other mental disorders	Video-conferencing group intervention	66	Mean age: 67.8	RCT, control: treatment as usual	Peer reviewed journal	Decrease in caregiver stress (3-point severity scale, RMBPC)
Odetti et al. (2007) (AIBO)	Dementia	Robotic pet	24	Mean age: 76.6	Experiment on acceptability (observation and single-item questions)	Conference proceedings	System was accepted
Pot & Blom (2009)	Dementia	Online counseling	60 (started, ongoing)	Not specified (caregivers of dementia patients)	Pre-post and follow-up comparisons (ongoing)	Conference proceedings	Not specified (ongoing)

Riikonen et al. (2010)	Dementia	Home-care: risk preventive, assistive and emergency technology	25	54–90	Explorative evaluation of various technical devices	Peer reviewed journal	Devices fostered independent living and decline in caregiver stress (NPI) in some cases
Schulz et al. (2003) (REACH)	Dementia	Various interventions for caregivers in 6 US sites (monitoring of stress and computerized telephone support)	100–257 caregivers (dependent on site)	Mean age: 61.1–68.5 (dependent on site)	RCTs, control: minimal support group or usual care	Peer reviewed journal	Improved coping; reduced stress and depression (dependent on site), main outcome measure: CES-D
Yonemitsu et al. (2002) (AIBO)	Dementia	Robotic pet	4	Not specified (older adults with dementia)	Direct observation	Peer reviewed journal	Increased communication
	Complex approaches			**55–85**			
Anfosso & Bourdeau (2009)	ADLs	Monitoring	2	64–85	Explorative test of system	Peer reviewed journal	System able to detect ADL levels

(GEROHOME)							
Basak et al. (2008)	Cognitive functioning	Game	40	Mean age: 68.88–70.05	Pre-post comparisons	Peer reviewed journal	Improvement in cognitive functions (APM and others)
Bestente et al. (2008)	Chronic disease	Monitoring	25	Not specified (older adults)	Development and test of a prototype	Peer reviewed journal	Not specified (system successfully tested)
Franco et al. (2008)	ADLs	Monitoring	13	Mean age: 83	Explorative test of system	Peer reviewed journal	System able to differentiate daily and nocturnal ADL levels
Gamberini et al. (2009)	Cognitive functioning and social interaction	Game	4 (usability evaluation) 107 (acceptance) 59 (monitoring cognitive abilities)	Mean age: 68	Usability studies and acceptance evaluation of prototype; pre-post comparisons	Conference proceedings	System user friendly and accepted, able to monitor cognitive abilities (fit with WASI)
Giotakos et al. (2007)	Mobility, rehabilitation	Virtual reality (VRET)	68	Mean age: 76.8	Pre-post and follow-up comparisons	Peer reviewed journal	Reduced fear of falling (FES-I) and increased balance confidence (ABC)

Hlauschek (2009) (VITALIshoe)	Mobility/safety: fall prevention	Instrumented shoe	Not specified (onging)	Not specified (older adults)	Development and evaluation of a prototype	Conference proceedings	Not specified (onging)
Huch (2009), http://www.hearmefeelme.org; (Hear Me Feel Me)	Sensory challenges	Mobile phone (NFC) technology, connected to Internet	Not specified (onging)	Not specified (older adults)	Development and evaluation of a prototype	Conference proceedings	Not specified (onging)
Khoo et al. (2009) (Age Invaders)	Physical and social interaction	Game	7	64–78	Development and usability studies of a prototype	Peer reviewed journal	Development of a system that fits the user's needs
Kizony et al. (2006) (TheraGame)	Rehabilitation	Virtual reality	16	65–76	Usability studies of the prototype, pre-post comparisons	Conference proceedings	Moderate to high levels of enjoyment (SFQ) and usability (SUS)
Rand et al. (2008) (Sony Playstation II EyeToy)	Rehabilitation	Virtual reality	22	50–80	Usability studies of the prototype, pre-post comparisons	Peer reviewed journal	System feasible for older adults and stroke patients (SFQ and SUS)
Reder et al. (2010)	ADLs	Monitoring	12	55+	Pre-post comparison (pilot study)	Peer reviewed journal	Satisfaction with the system; increase in

perceived safety, well-being, peace of mind and independence; qualitative interviews

Note: CAPS = clinician-administered PTSD scale; SCL 90 = Symptoms Checklist; RCT = Randomised Controlled Trial; PDS = Posttraumatic Stress Diagnostic Scale; BSI = Brief Symptom Inventory; BDI = Beck Depression Inventory; WHO-5 = WHO-Five Well-being Index; LAP-R = Life Attitude Profile–Revised; RQ = Reminiscence Questionnaire; QUIDS = Quick Inventory of Depressive Symptoms; SF36 = MOS 36-item Short-Form Health Survey; RBANS = Repeatable Battery for Assessment of Neurocognitive Status; HAMD = Hamilton Depression Scale; ABMI = Agitated Behaviours Mapping Instrument; KMLT = Knowledge about Memory Loss Test; RMBPC = Revised Memory and Behavior Problems Checklist; NPI = Neuropsychiatric Inventory; CES-D = Center for Epidemiologic Studies – Depression Score; ADLs = Activities of Daily Living; APM = Raven's Advanced Progressive Matrices; WASI = Wechsler Abbreviated Scale of Intelligence; VRET = Virtual Reality Exposure Therapy; FES-I = Falls Efficacy Scale – International; ABC = Activity-Specific Balance Confidence; SFQ = Short Feedback Questionnaire; SUS = System Usability Scale.

Conclusion

This literature review of e-health interventions targeting three of the most frequent mental disorders in old age – depression, anxiety disorders, and dementia – has identified a variety of studies and ongoing projects, the initial results of which are promising. We considered ICT solutions such as Ambient Assisted Living (AAL) and Smart Home technologies designed to compensate for or prevent health-related changes or to foster active aging in old age, as well as game-based applications and training programs. Our literature review included peer reviewed papers and randomized controlled trials as well as conference proceedings (i.e., ongoing projects) and papers reporting the results of pilot studies. Overall, the studies reviewed involved a total of 965 participants aged 65 years and above. There is a growing interest in this field and the idea of fostering active and healthy aging unites a variety of research fields and professions. Beyond the areas described in this literature review there are also new research areas developing. For example, *Second Life* has been used to entertain older people and overcome social isolation and loneliness (Boulos, Hetherington & Wheeler, 2007) and *Robot Suit HAL* (Hybrid Assistive Limb) has been shown to be a helpful device in the assistance of the user's limbs (e.g. the support of movement of arms and legs of older or disabled individuals; Sankai, 2006).

Our findings underline that research in the field of e-health for older individuals is still in its early stages. As previously reported (Broekens et al., 2009; Chan et al., 2009; Charness & Boot, 2009; Erren-Wolters et al., 2007), methodological quality varies, and there is a lack of randomized controlled trials (RCT) and robust research designs (much research to date has been limited to pilot and short-term studies). To our knowledge, findings from only one completed RCT study on e-health and depression in old age (Spek et al., 2008; Spek, Nyklicek, et al., 2007) and three

completed RCT studies on e-health and dementia in old age (Mahoney et al., 2002; Marziali & Donahue, 2006; Schulz et al., 2003) have yet been published.

Further, it remains to be seen whether prototypes investigated will reach the final phase of implementation and can be placed on the market. In addition, ethical and legal issues and individual needs warrant particular consideration in this context, especially where monitoring devices are concerned (Chan et al., 2009; Charness & Boot, 2009). Beyond these challenges, we identified some high-quality research and a variety of innovative ongoing research and pilot studies in the field. The promising results of these studies indicate that ICT may in the future be able to make a significant contribution to active and healthy aging.

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